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HOW TO DETECT SNOW FALL OCCURRENCE DURING BLOWING SNOW EVENT?

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ABSTRACT: In mountainous areas, drifting snow influences the spatial distribution of the snow cover and consequently snowpack stability and avalanche risk. When comparing models with in situ-measurements, it is first necessary to identify snow-drift events with and without concurrent falling snow. In Antarctica, the mass balance of the Antarctic ice sheet is a key parameter of sea level rise, which can be moderated by accumulation change. However, in the coastal areas where katabatic winds are strong and frequent, it is necessary to identify and separate blowing snow and precipitation.

It was shown that size distribution of blowing snow particles given by a snow particle counter at a specific height can be approximated by a two-parameter gamma probability function and that a bi-modal distribution could appear at high elevation when snow fall occurs (Nishimura and Nemoto, 2005). In such way, it could be possible to evaluate precipitation.

But depending on the height, the size of snow fall particle and the wind speed it is not so easy to distinguish between both types of events. In such case, the analysis of snow flux and mean diameter according to wind speed allows to separate blowing snow event with and without precipitation. It gives better results in predicting the timing of precipitation than done by precipitation gauges. A simpler photoelectric counter such as designed by Wenglor could also give some interesting results. These conclusions are supported by field campaigns conducted in French Alps and in Antarctica (coastal Adélie Land) during last winters.

KEYWORDS: Blowing snow, drifting snow, snow fall, precipitation, sensor, Alps, Antarctic

1. INTRODUCTION

In mountainous areas, drifting snow influences the spatial distribution of the snow cover and consequently snowpack stability and avalanche danger. When comparing models with in situ-measurements, it is first necessary to identify snow-drift events with and without concurrent falling snow. In Antarctica, the mass balance of the Antarctic ice sheet is a key parameter of sea level rise. However, in the coastal areas where katabatic winds are strong and frequent, it is necessary to identify and separate blowing snow and precipitation.

In mountainous areas but also in Arctic or Antarctic continent falling snow is rapidly redistributed by wind. In such conditions not only accurate measurement of precipitation but also detection of precipitation is a challenge. The blowing snow billow can be very high up to several hundred meters (Scarchilli et al., 2010).

So the measured snow water equivalent suffers of high uncertainty whatever is the position of precipitation gauge. Present weather sensors such as VPF730 (Bellot et al., 2011) are also unable, at the present time and without any additional treatment, to distinguish between falling and blowing snow. Empirical methods based on sensors (wind, precipitation and snow depth sensors, Webcam) were developed too but are not enough accurate (Vionnet et al., 2011). Nishimura and Nemoto (2005) showed that a Snow particle counter (SPC-S7) set at a specific height, preferably higher than 10 m, can be used to evaluate precipitation because in this case a bi-

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modal distribution could appear. But depending on the height, the size of snow fall particles and the wind speed it is not so easy to identify this bi-modal distribution. That is why we turn to the concomitant analysis of snow flux, mean diameter and wind speed to detect blowing snow event with and without precipitation. First data stemming from SPC-S7 are analyzed. Then a simpler photoelectric counter designed by Wenglor Sensoric gmbh is also tested for this purpose. The results are supported by field campaigns conducted in French Alps and in Antarctica (coastal Adélie Land) during the last winters.

2. BLOWING SNOW EVENTS WITH AND WITHOUT SNOW FALL DETECTED BY A SNOW PARTICLES COUNTER (SPC-S7)

2.1 *Snow particles Counter SPC-S7*

The snow particle counter (SPC-S7, Niigata electric) (figure 1) is an optical device (Nishimura and Nemoto, 2005). The diameter and the number of blowing snow particles are detected by their shadows on photosensitive semiconductors. Electric pulse signals of snow particles passing through a sampling area are sent to an analyzing logger. In this way the snow particle counter detects particles between 20 and 250 μm in mean radius size particle, divides them into 32 classes, and records the particle number every 1 s. Assuming spherical snow particles, the horizontal snow mass flux q is calculated as follows:

$$q = \sum q_d = \frac{\sum n_d \frac{4}{3} \pi \left(\frac{d}{2} \right)^3 \rho_p}{S * t} \quad (1)$$

Where q_d is the horizontal snow mass flux for the diameter d , n_d is the number of drifting snow particles, S the sample area, t the sample period, and ρ_p the density of the drifting snow particles (917 kg m^{-3}).

2.2 *Alps field experiment configuration*

Lac Blanc Pass (French Alps) is located at the Alpe d'Huez ski resort near Grenoble, France. The large north-south-oriented pass, 2800 m high, consists of relatively flat terrain over a length of about 300 m where blowing snow has been studied for twenty years by IRSTEA (previously Cemagref) and Meteo France. This experimental

site is presented in details in this proceeding (Guyomarc'h et al., 2012).

The measurements presented here are done during winter 2010-2011 and 2011-2012.

Three Snow Particles Counters (figure 3) were installed on mast. One SPC was set up at a fixed position (4.4 m above the ground). Two others were set up near the snow pack surface. A fixed distance of one meter separates them. These two SPC and two cup anemometers set up at the same height could be raised manually when the snow depth increases and buries the sensors. A snow depth sensor (figure 2) that measures the exact position of the SPC above the snow pack and an ultrasonic anemometer supplements these devices.



Figure 1: Snow Particles Counter



Figure 2: Ultrasonic anemometer and snow depth sensor (Jenoptik)



Figure 3: Sensors deployed at Lac Blanc pass allowing to obtain the measurements presented here.

2.3 Detection of snow fall during blowing snow event

During blowing snow event without precipitation it is known that the size distribution of snow particles at a specific height can be accurately approximated by the means of the two parameters gamma probability density function (in red in figures 4 and 5). As previously stated, during snow fall at a specific height, preferably higher than 10 m, we can observe a bi-modal distribution in Antarctica. But at Lac Blanc pass, it is not often the case even if blowing snow occurs with concurrent precipitation at least 37% of time (Vionnet et al., 2012).

It must be noticed that the highest SPC is set up at 4.4 m above the ground. Depending on the height, the wind speed and the snow particles size, the snowfall contributions can be hidden behind the large contribution of blowing snow particles (figure 5) and it is not always so easy to detect the bi-modal distribution. That's why we choose to develop a method based on combined analysis of wind and drift sensors.

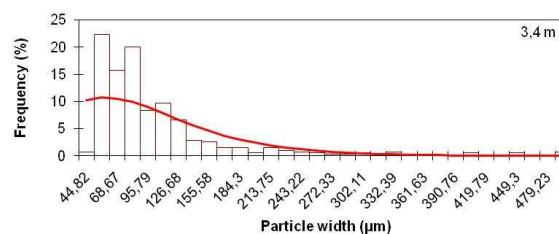


Figure 4: Particle diameter distributions measured with the highest SPC (blowing snow event with snow fall - 2011-02-23 4H00)

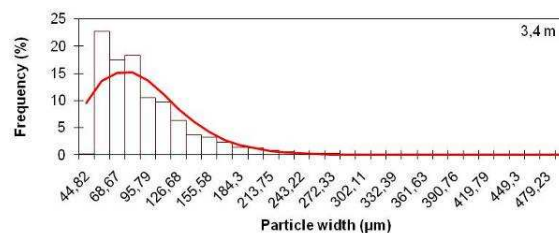


Figure 5: Particle diameter distributions measured with the highest SPC (blowing snow event without snow fall - 2011-02-24 23H40)

During blowing snow event without concurrent falling snow, snow mass flux as function of wind speed fits with a power law. Such feature allows

distinguishing blowing snow events with and without snowfall. It is easier to detect in the highest layers (figures 6, 7, 8). Nevertheless the different types of events can be distinguished from 1, 2 m high. Exact transitions between events remain difficult to detect.

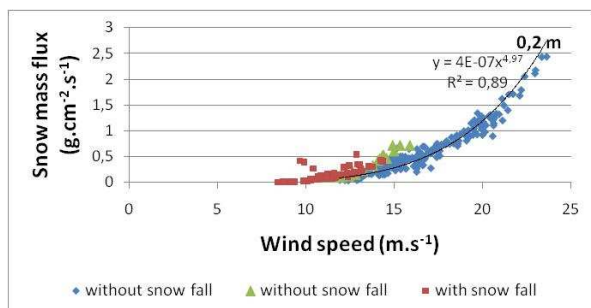


Figure 6: Horizontal snow mass flux at 0.2 m high plotted against wind velocity from 23 to 26 February 2011

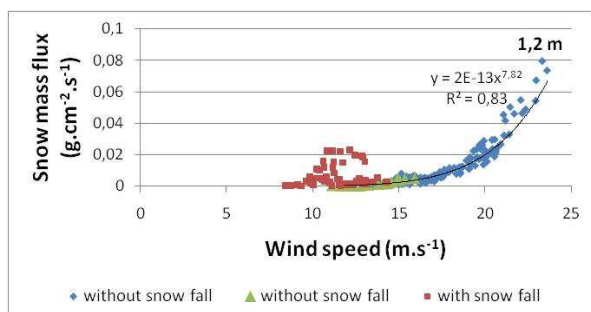


Figure 7: Horizontal snow mass flux at 1.2 m high plotted against wind velocity from 23 to 26 February 2011

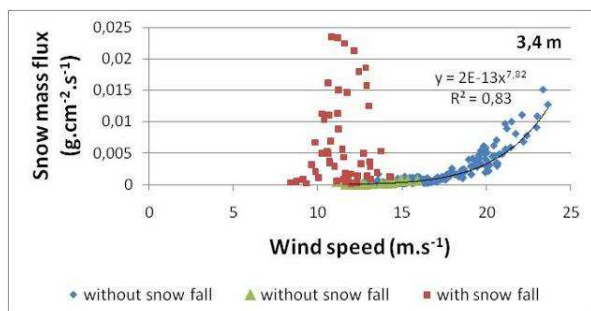


Figure 8: Horizontal snow mass flux at 3.4 m high plotted against wind velocity from 23 to 26 February 2011

A more detailed analysis of physical processes involved during blowing snow event without concurrent falling snow can be conducted and could improve the prediction.

- The snow particles diameter declines with height above the snow (figure 9)
- Larger particles are being carried aloft at higher wind speed (figure 10)

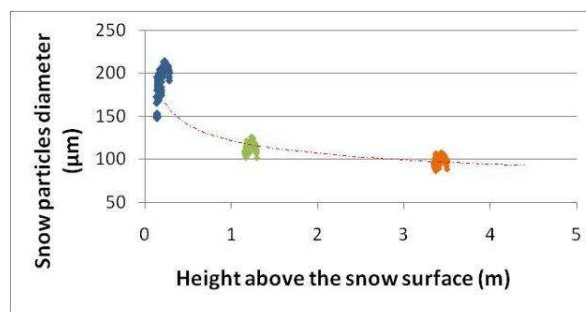


Figure 9: Snow particles diameter plotted against height above surface during blowing snow events without falling snow from 23 to 26 February 2011

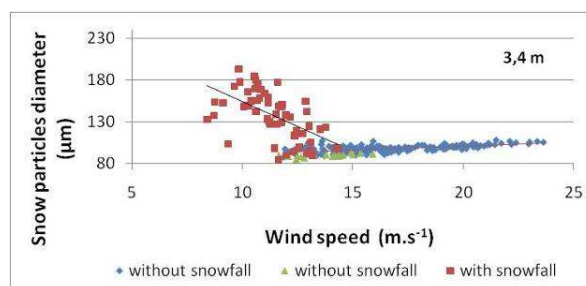


Figure 10: Snow particles diameter plotted against wind velocity from 23 to 26 February 2011.

Previous example can be considered as a "textbook case" and sometimes the events are not easy to characterize (figure 11).

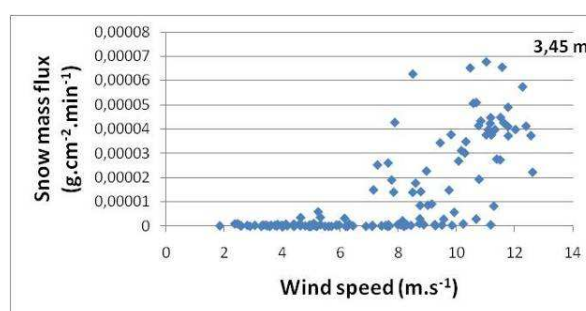


Figure 11: Horizontal snow mass flux at 3.4 m high plotted against wind velocity from 20 to 21 February 2011

In these case, the more detailed analysis based on snow particles diameter allow to conclude that snow falls occurred during this event. But precipitation gauges set up at Lac Blanc Pass did not detect any snow fall. Nevertheless other

precipitation gauges recorded snow fall in a nearby area protected from wind at 1800 m a.s.l. and experimenters present at Lac Blanc Pass at this period confirmed the presence of snow fall. As conclusion this method gives better results in predicting the timing of precipitation than those obtained with precipitation gauges.

3. BLOWING SNOW EVENTS WITH AND WITHOUT SNOW FALL DETECTED BY A COMMERCIAL PARTICLE-COUNTING DEVICE (WENGLOR®)

3.1 *The Wenglor® sensors (YH03PCT8 and YH08PCT8)*

The Wenglor® sensors (YH03PCT8 and YH08PCT8), names Wenglor thereafter, consist of a laser (655 nm), photo sensor, and switching circuit (figure 12). When a particle passes through the 0.6 mm diameter, 30 mm (80 mm depending on the model) long laser beam, the sensor outputs a digital signal which is recorded on a data logger. This sensor is not capable of size discrimination but its main advantages are low cost and low power requirement which is essential in Antarctica. As far as we know, Leonard (Leonard and Cullather, 2008, Leonard et al., 2011) was one of the first researchers who proposes and tests the use of the Wenglor commercial particle-counters to quantify drifting snow.

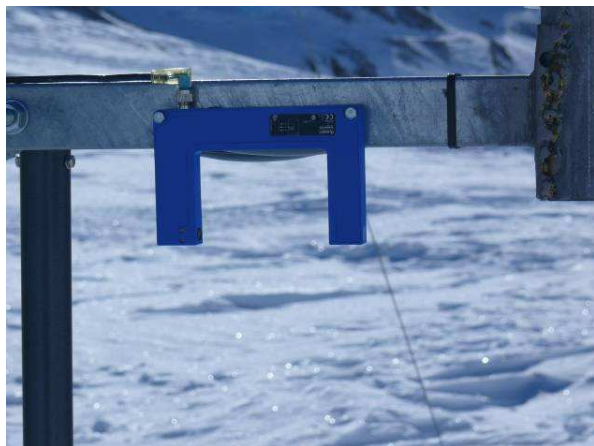


Figure 12: Wenglor sensor deployed at Lac Blanc Pass

3.2 *Alps field experiment configuration and results*

The Wenglor and the SPC have been compared in a side-by-side deployment (figure 3) at Lac Blanc

Pass in the winter of 2011-2012. SPC has a smaller particle size detection threshold than Wenglor. That's why it records far more particles. But despite this fact and for the studied blowing snow event (figure 13), there is a linear relationship between Wenglor particle count per 10 minutes and the average value of snow mass flux over 10 minutes calculated by the SPC-S7.

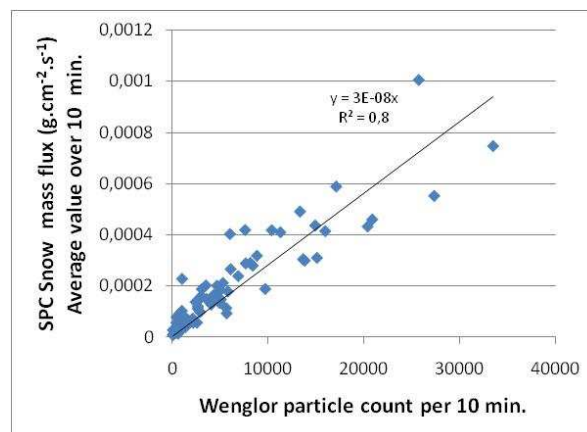


Figure 13: Particle count measured by the Wenglor sensor at 3.4 m high plotted against snow mass flux from 10 to 11 April 2012

In such way, the shapes of the curves linking wind speed to particle count and wind speed to snow mass flux are similar (figures 14 and 15). Similar analysis than those presented in section 2.3 can be done with Wenglor sensors. But we have to keep in mind that additional information concerning the snow particles diameter is no more available. Consequently it will be less accurate.

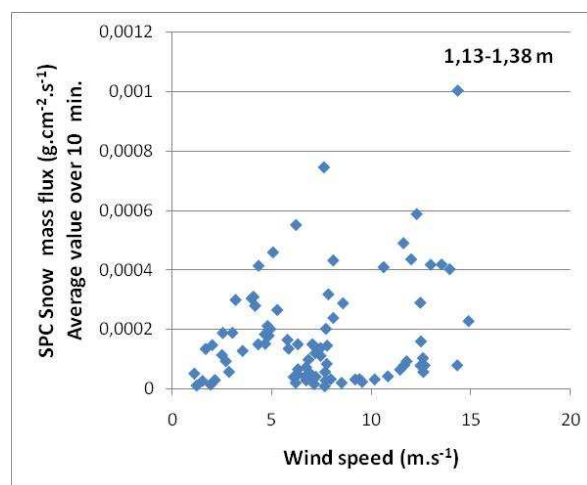


Figure 14: Horizontal snow mass flux at approximately 1.2 m high plotted against wind

velocity from 10 to 11 April 2012 at Lac Blanc Pass

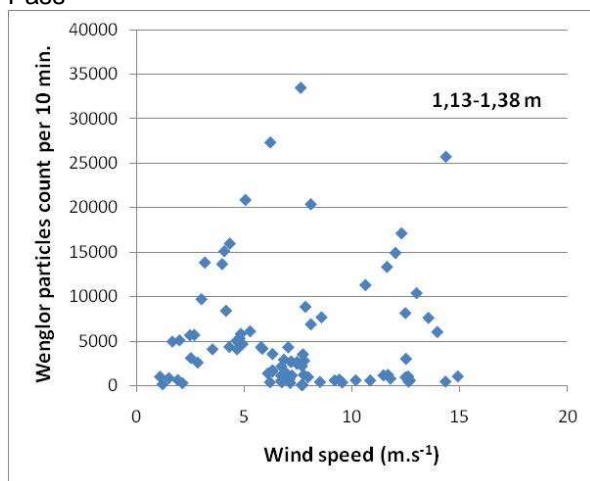


Figure 15: Particle count measured by the Wenglor sensor at approximately 1.2 m high plotted against wind velocity from 10 to 11 April 2012

3.3 *Antarctica field experiment configuration and preliminary results*

Two Wenglor sensors have been deployed in Adélie Land which is located in East Antarctica and continuously swept by very strong katabatic wind. The automatic snow station D17 (figure 16), on which the sensors have been set up, is situated 9 km from the coast (66.724 S, 139.706 E, 465 m a.s.l.)



Figure 16: Automatic Snow Station D17

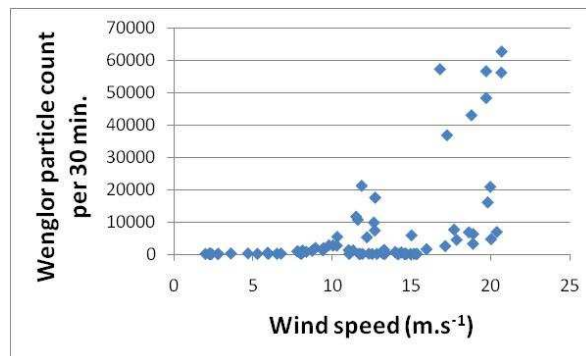


Figure 17: Particle counts measured by the Wenglor sensor at 1.3 m high plotted against wind velocity from 9 to 12 January 2012 at Automatic Snow Station D17

Data (figure 17) seem to indicate that two snow fall events occur during this blowing snow storm. Nevertheless these data must be handled with caution, due to occasional sensor null value that are abnormal and which can be due to low temperature and/or light saturation. Laboratory experiments to test these hypotheses are in progress.

CONCLUSIONS AND PERSPECTIVES

The analysis of snow flux and mean diameter according to wind speed allows to separate blowing snow events with and without precipitation. It gives better results in predicting the timing of precipitation than those obtained with precipitation gauges. Even if it is less accurate a simpler photoelectric counter such as designed by Wenglor could also give some interesting results. Nevertheless this sensor still needs some tests and perhaps some improvements to be used in Antarctica under harsh conditions during several months. The next step will aim at evaluating precipitation (Leonard and Cullather, 2008).

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